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ABSTRACT

Most studies of eye movement behavior during reading have dealt with the processes involved with local aspects of text, such as visual or graphic characteristics or individual word features. To determine if a global level of processing (pertaining to the whole text or to large sections of it) would affect eye movement patterns differently, a study examined the pattern of movements of skilled adult readers as they encountered stories with surprise endings. The subjects, 22 college students, read three surprise-ending stories while their eye movements were monitored. As a control condition, some students read versions of the stories that had been rewritten to give away the surprise at the beginning. Results showed an increase in the number of fixations associated with rereading the surprising lines of the stories when compared to the same lines in the control condition versions. There was also a small increase in the mean duration of fixations on the surprising lines, but there was no change in mean saccade length. The findings suggest that even the most global levels of processing must be considered as an influence on the eye movement control system. A three-page list of references and graphs concludes the report. (FL)

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CENTER FOR THE STUDY OF READING

Technical Report No. 344

COMPREHENSION PROCESSES AND EYE MOVEMENT PATTERNS IN THE READING OF SURPRISE-ENDING STORIES

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CS 008 249

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Abstract

This study investigates the pattern of eye movements of skilled adult readers when encountering a surprise ending to a story. Subjects read three surprise-ending stories while their eye movements were being monitored. As a control condition, some of the stories they read gave the surprise away at the beginning. There was an increase in the number of fixations associated with rereading the surprising lines of the stories when compared to the same lines in the control condition. There was also a small increase in the mean duration of fixations on the surprising lines, but there was no change in mean saccade length. These results suggest that even the most global levels of processing must be considered as an influence on the eye movement control system.

Comprehension Processes and Eye Movement Patterns in the Reading of Surprise-Ending Stories

Recently, there has been interest in using eye movement behavior to study immediate on-going mental processes during reading. Most investigations have centered on processes related to more local aspects of the text, such as the visual or graphic characteristics or individual word characteristics like word frequency and part of speech. There has been some research on processes that link individual sentences together at a local level in the text (Carpenter & Just, 1977; Just & Carpenter, 1978; Kennedy & Pidcock, 1981; Scinto, 1978). Few studies, however, have centered on processes involved with more global aspects of comprehension, processes that pertain to whole texts or large sections of text. Mandel (1979) and Shebilske and Fisher (1981) have shown differences in eye movement patterns on sections of text that express more important ideas, and Rothkopf and Billington (1979) have shown eye movement pattern differences between text sections which differ in their importance with respect to the reader's goals. Similarly, Inhoff (1983) has shown differences in fixation duration as a function of the predictability of words within the text context.

In this study, subjects' comprehension processes were manipulated at the most global level. Iran-Nejad (1984) has provided evidence that a complete change in the mental representation of the entire text occurs when people read and comprehend surprise-ending stories, which does not occur when these same stories are rewritten so as to give away the

surprise at the beginning of the text. In the current study, three surprise-ending stories similar to those used by Iran-Nejad (1984) were used. These stories are organized so that critical expository or event information is omitted from the beginning of the text and then is inserted later in the text (this is what Brewer and Lichtenstein (1981, 1982) classify as a surprise discourse structure). Upon reaching the omitted information, the reader is surprised and must reinterpret the underlying global representation of the discourse (Iran-Nejad, 1984). We were interested in whether this change in global representation would manifest itself in distinctive eye movement patterns around the area of text presenting the surprising information. To provide a control condition, the stories were rewritten so that the surprise ending was given away at the beginning of the story. In both the surprising and non-surprising versions, the base text was identical; the only difference was the addition of the give-away information at the beginning of the control text. With this design, we were able to compare the reading of exactly the same physical text when it was and was not surprising. The potentially surprising area of text has exactly the same local properties in both versions (in terms of visual, lexical, syntactic, and local intersentential information), the only difference being the relationship of these text sections to the global properties of the text.

Exploring the effects of global comprehension processes on eye movement patterns, while controlling the effects of processes at other levels, has implications for theories of eye movement control. The results will indicate whether global aspects of comprehension have any

effects on eye movements and, if so, whether or not global and local processing have different effects on eye movement patterns.

Methods

Subjects

Twenty-two graduate and undergraduate students at the University of Illinois were used as subjects. They were all skilled readers. To participate, subjects had to have normal uncorrected vision and could not have certain ocular or facial characteristics which made eye movement monitoring difficult.

Apparatus

The text was displayed one line at a time on a DEC Model VT-11 display unit. The text appeared in upper and lower case characters. The distance between the subject and the cathode-ray tube of the display unit was 68 cm. which made one degree of visual angle equivalent to approximately 4 character positions. The subject was given a button which called up new lines of text on the display unit. This allowed subjects to read multi-line passages one line at a time at their own pace. Subjects could not go back and reread a prior line, although they could reread the line they were currently viewing. Eye movements were monitored with a SRI Dual Purkinje Image Eyetracker. Both the computer and the display unit were interfaced with a DEC PDP-11/40 computer, which sampled eye position every millisecond.

Materials

Three surprise-ending stories were adapted from Ellery Queen's Mystery Magazine. There were experimental and control versions of each story. In the experimental versions the stories were left in their original surprising form. The control versions were identical to the experimental versions, except for the addition of several sentences at the beginning of the story which gave away the surprising information.

The first story will be referred to here as Gabriel. It is 879 words in length in the experimental version and 1214 words in length in the control version. In the story, Marilyn is driving home from the hospital late at night, thinking about the recent surge in muggings and murders. She drives into a gas station. While she is there, the attendant, Gabriel, asks her to come to his office to see his birthday present. Despite her alarm, she does so, and Gabriel pulls out a gun. He then tells her that he spotted a strange man hiding on the floor in the back of her car, and calls the police.

The second story, referred to as Lion, is 1041 words in length in the experimental version and 1108 words in length in the control version. In this story, the narrator describes his imprisonment under horrible conditions. On the last line of the story, the narrator proclaims that his prison is called the San Diego Zoo and his name is Lion. This story hinges, of course, on the reader's expectation that the narrator is a human being, and the surprise comes when the reader is informed otherwise.

The third story, referred to here as Sally, is 997 words in length in the experimental version and 1259 words in length in the control version. George, a camper, wakes up in his tent and calls for Sally. However, he is then forced out of his tent by a man carrying an ax and a shotgun. The man, an escaped criminal, threatens to kill George's wife, Sally. George tries to explain that Sally is not his wife, but the criminal does not listen. Then, George calls for Sally and throws a knife at the criminal, but misses. The criminal raises his ax and comes toward George. Just then Sally appears. Sally is a huge, powerful dog who subdues the criminal. The reader is uncertain of Sally's identity, although one is led to believe she is a human being, and the surprise comes when the reader learns she is George's dog.

Procedure

Subjects were fitted to a bitebar and headrest in order to minimize head movements. They were instructed in the use of the button to change lines. Most of the subjects were familiar with the procedure because they had participated in previous studies. Also, prior to reading the stories, they were instructed to give the experimenter a short verbal summary of each story after they finished reading it. Subjects read either a control or experimental version of each of the three stories. Each subject received at least one of the three stories in the original surprising version. The order in which subjects read the three stories was counterbalanced across subjects. Finally, after each story, subjects were asked if they had been surprised by the ending.

Results

Eye movement parameters can be viewed as the constituent components of total reading time (Kennedy & Pidcock, 1981). That is, if there is an increase in reading time, the increase could be due to an increase in the duration of fixations, an increase in the number of fixations made, or both. Furthermore, an increase in the number of fixations can be due to a decrease in the average distance between fixations (i.e. some or all fixations occur closer together), an increase in the frequency of backward (regressive) movements and/or rereadings, or some combination of these two. The presentation of the results will be organized in these terms: a change in reading time between the experimental and control text versions will be shown, and then the character of the eye movements will be examined to show what aspects of the eye movement pattern changed to produce this increase.

The lines which first introduced the surprising information were selected for each story. For Lion, the very last line of the story was the only line which contained surprising information. For the other two stories, three lines were selected over which the surprising information was gradually revealed. Subjects must have become surprised by the time they reached the last of the three critical lines. The text of these lines was identical for the experimental and control versions. The data from these lines were selected for the analysis presented here.

Due to various reasons, data from some subjects was lost for some of the stories. The result was that. for the experimental versions, data

came from 12 subjects for Gabriel, 9 subjects for Lion, and 11 subjects for Sally, and for the control versions, data came from 10 subjects for Gabriel, 11 subjects for Lion, and 11 subjects for Sally.

Reading Time

Table 1 presents the mean reading times in milliseconds. There was a significant increase in reading time on the selected lines in the experimental condition when compared to the control condition ($F(1,141) = 14.85$, $p < 0$). Therefore, reading time increases simply as a function of comprehension processes associated with the surprise and reinterpretation process discussed above. An examination of the reading times for individual lines shows that there was a significant increase in reading time in Gabriel for the second ($F(1,20) = 8.94$, $p = .01$) and third ($F(1,20) = 4.83$, $p = .04$) selected lines. The critical line of Lion showed a significant increase ($F(1,18) = 4.35$, $p = .05$) and the first of the selected lines in Sally showed a significant increase ($F(1,17) = 5.58$, $p = .03$).

Insert Table 1 here

Thus, simply using overall reading time, the area of the text at which the surprise and global reinterpretation process commonly occurs can be identified. We attempted to even further localize the point at which subjects become surprised (on the average) by plotting the average

cumulative reading time for each letter position on the lines which showed a significant increase in reading time. For each of the 73 possible letter positions on the line, the amount of elapsed reading time it took to reach that position was obtained for each subject. This produces a step-like function of gradually increasing cumulative reading time. For each letter position, the cumulative reading times from each subject were then averaged together, thus producing a graph of the average time it took the subjects' eyes to reach each letter position on the line (for a similar technique see O'Regan, 1980). An average cumulative reading time curve was plotted for the experimental and the control data.

Because the average reading time is longer in the experimental condition, the average cumulative reading time curves for the two conditions will differ. The position on the line at which the surprise manipulation first had an effect will correspond to the point at which the two curves separate. The curves for the lines which demonstrated reading time differences are presented in Figures 1-4. These curves do show that a specific point can be shown to exist where the increase in reading time was first manifested.

Insert Figures 1-4 here

General Differences in Eye Movements

First, we can ask whether this increase in reading time is due to an increase in fixation durations, an increase in number of fixations made, or in a combination of both. To analyze fixation durations, fixations were first classified into two different categories: first pass fixations and rereads. Rereads were defined as fixations which occurred to the left of a point at which the eye has previously fixated to the right. Thus, rereads include fixations associated with regressions and fixations associated with forward moves making a second pass across the text. For all populations of fixations examined, fixations associated with eye blinks and cases where the eyetracker did not track the eye properly were eliminated, and all fixations greater than 1 second in duration were also eliminated.

Table 2 presents the means and standard deviations for fixation durations on the selected lines of the three passages. The mean fixation duration of first pass fixations was 212 ms for the surprising lines of the experimental condition stories and 202 ms in the control condition. This small 10 ms increase was significant ($F(1,890) = 4.98$, $p = .03$). The increase in mean fixation duration was about the same for reread fixations, the mean fixation duration was 212 ms in the experimental condition and 200 ms in the control condition. This 12 ms increase was not significant. Whatever actual effects on fixation duration there may be, those effects are small and surely cannot be the only eye movement component contributing to the increase in reading time.

Insert Table 2 here

There were also differences between passages in terms of the size of the increase in mean fixation duration in the experimental condition relative to the control condition. The increase in first pass fixation duration seems largely confined to the Gabriel and Lion passages. There is a significant 22 ms increase in mean fixation duration for Gabriel ($F(1,366) = 7.33$, $p = .01$), and a 16 ms increase for Lion which is not significant. For reread fixations, if one outlier is removed from the data, there is a large 38 ms increase in the mean duration in the experimental condition for the Lion passage ($F(1,79) = 3.85$, $p = .05$). There is a nonsignificant 16 ms increase for Sally, and no increase for rereads in Gabriel.

In contrast, the surprise and reinterpretation process appears to produce a very significant increase in the number of fixations made on the surprising lines. There is an average of 10.68 fixations per line in the control condition and an average of 13.46 fixations per line in the experimental condition, a significant difference ($F(1,141) = 13.49$, p ~ 0). Each passage likewise shows a significant increase in average number of fixations per line in the experimental condition. This is a very crude measure. in that it does not take account of the length of each line, but it clearly shows that the major if not only source of the increase in reading time due to the surprise manipulation is an increase in the number of fixations made. This indicates that there is a change in the pattern

of fixations made in the surprising versions of the stories. The next question to ask is what specifically changes in the pattern of fixations which results in an increase in overall number of fixations.

Differences in Eye Movement Patterns

There are two general kinds of patterns which will produce an increase in the number of fixations: the distance between fixations may be shorter (which is to say, saccade lengths become shorter) or there may be an increase in the number of backward movements, i.e. in the number of regressions and second passes across the lines. An examination of the percentage of fixations in the data classified as first pass or reread fixations indicates that the latter pattern is occurring as a result of the surprise and reinterpretation process. In the control condition, 84% of the fixations are first pass fixations and 16% are rereads. whereas in the experimental condition, 68% of the fixations are first pass fixations and 32% are rereads. The corresponding frequencies here are significantly different by a chi-square test ($X^2(1) = 41.60$, $p \sim 0$). Thus, an important manifestation of the comprehension of surprising information is a tendency to more frequently reread surprising than non-surprising information. Furthermore, many more of these reread fixations are preceded and followed by forward saccades, 9% of the rereads in the control condition versus 27% of the rereads in the experimental condition. It appears that readers are more frequently making a true second pass through some section of the line when reading the surprising version. Table 3 presents the percentage of reread and first pass fixations in the slected lines of the experimental

and control versions of each of the three passages. These results appeared in all the passages, although the tendency to reread was larger in Lion than in the other passages.

Insert Table 3 here

Finally, the effect of the surprise manipulation on saccade lengths was examined. Table 4 presents the mean saccade lengths for saccades which precede first pass and reread fixations. A two way analysis of variance was done using the fixation classification (first pass versus reread) and experimental condition (surprise versus no surprise) as the factors. Only the main effect of fixation classification was significant ($F(1,1434) = 32.85$, $p \sim 0$); the effect of condition and the interaction were not significant. This indicates that the surprise and reinterpretation process did not produce smaller saccades, i.e. more closely spaced fixations. Fixations were, on the average, not any closer together; rather, there were more fixations as a result of backward patterns of movement across the text.

Insert Table 4 here

Discussion

This experiment manipulated subjects' comprehension processes at the most global level; it forced a complete change in the mental representation of the entire discourse. At the same time, local aspects of processing were kept constant, as the texts read were visually identical. The result of the surprisingness manipulation, compared to the control condition, is to increase reading time on the portion of text introducing the surprising information. The major change in eye movement patterns, as a result of the surprise and reinterpretation process, is to increase the number of fixations associated with the rereading of the text. In addition to the increase in time spent rereading the text, subjects may have also been making longer fixations, although this latter effect is small and may not be reliable. Clearly, there is an effect on the pattern of eye movements, and models of eye movement control will have to take into account the influence of processing at the global level as well as the more local level of processing.

Does this global level of processing affect eye movement patterns in a different way than more local processing? Changes in fixation durations are a common finding for studies which manipulate visual and lexical aspects of texts (see McConkie, 1983, for a review). Such effects are usually much larger than the rather weak effect found here. Interestingly, the surprise effects observed here did not seem to alter saccade length, which has been found to be sensitive to the manipulating of certain perceptual processes. Changes in fixation duration and

interfixation distance have been found as a result of manipulation the importance of a section of text (Shebilske & Fisher, 1983). The increased rereading of the text has not been reported as an effect of manipulating visual or lexical aspects of texts, but changes in the pattern of regressive eye movements have been reported as the result of manipulating syntax, intersentential inferences, and importance (e.g. Carpenter & Just, 1977; Frazier & Rayner, 1982; Just & Carpenter, 1978; Rayner, Carlson, & Frazier, 1983; Shebilske & Fisher, 1983). It may be that there is a tendency for global processing to have global eye movement effects (i.e. effects on the overall inspection pattern), and local processing to have more localized eye movement effects.

Why would there be more rereading of the surprising text? Two hypotheses are compatible with the current data. According to the double-take hypothesis, the effect of the comprehension of surprising information is to cause the system to go back and recheck the visual information, that is, to go back and re-register the perceptual information, perhaps to verify that the schema-discrepant information was actually there. This sort of explanation is commonly held to be the purpose of regressions (e.g. Mitchell, 1982). Some support for this hypothesis comes from experimental situations where regressions are found to be directed at a specific region or lexical element in the text (Carpenter & Just. 1977; Ehrlich. 1983; Just & Carpenter. 1978). Another possible hypothesis is the suspension hypothesis, which states that the increased processing puts the mind into a state where it is not ready to incorporate new visual information from the text. As a result, the eye

movement system is "put on hold," regressions and rereads are made to hold the eye at one place until the comprehension processes are ready to acquire new information. Under this hypothesis. fixations which are followed by regressions will be located on specific, relevant parts of the text, but fixations preceded by regressions may not be located at any specific region relevant to the processing demands that produced the regression. Further research is necessary to examine these two hypotheses.

If different kinds or aspects of processing during reading produce qualitatively different effects on eye movements, then eye movements may provide more information than reading time for the researcher interested in cognitive processes. Our current state of knowledge of the eye movement control system does not allow us to say how different aspects of the eye movement pattern might be linked to different cognitive processes. In studies like the present one, it is difficult to attach any meaning to why one aspect of eye movements may be changed and not others. Full usefulness of such information awaits progress in understanding eye movement control during reading.

Finally, there is another aspect of this study which should be mentioned. Previous studies which have manipulated suprise ending stories have examined subjects' judgements about those stories or subjects' judgements about their affective response to those stories (Brewer & Lichtenstein, 1981; Iran-Nejad, 1983). This is the first experiment to demonstrate differences in real-time processing as a result of

manipulating the discourse structure of surprise-ending stories. Effects of understanding a story at a global level can be observed during the on-going process of comprehension.

The affective response, i.e. the subjective response of surprise, is concurrent with the cognitive response to the surprising information. It could be speculated that the reading time and eye movement differences observed here might be only due to the affective response or only to the cognitive response, the reinterpretation of the global representation. However, the subjects' response to the surprising information could also be viewed as a unified one, the affective and cognitive responses being aspects of the same mental activity, in which case it would make no sense to separate the two.

Summary

This experiment demonstrates differences in reading time and in eye movement patterns that are due to comprehension processes at a very global level. Comprehension of surprise-endings has not been studied in this way before. It was suggested that even the most global levels of processing must be seriously considered as influencing the eye movement control system. And finally, the results of this study hold promise for the use of eye movement data as a fruitful way to explore aspects of comprehension during reading.

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Table 1

Mean Reading Times for Selected Lines of Surprising and Non-surprising Passages

Passage/Line	Control	Experimental
All passages		
	2613	3401
Gabriel		
1	2545	2720
2	1810	3095
3	2213	2818
Lion		
	3110	4750
Sally		
1	2746	3388
2	2981	3873
3	3019	3084

Note. Reading times are in milliseconds.

Table 2

Summary Statistics for Fixation Durations in Selected Lines of All Passages

	Control			Experimental		
Fixation category	N	M	SD	N	M	SD
First pass	384	202	70	508	212	73
Reread	90	200	100	277	212	91

Note. Fixations durations are in milliseconds.

Table 3

Percentage of Fixations Classified as First Pass and Reread Fixations in Selected Lines of Each Version of Each Passage

Passage/Category	Control	Experimental
Gabriel		
First pass	90	75
Reread	10	25
Lion		
First pass	78	58
Reread	22	42
Sally		
First pass	80	67
Reread	20	33

Table 4

Summary Statistics for Saccade Lengths in Selected Lines of All Passages

	Control			Experimental		
Fixation category	N	M	SD	N	M	SD
First pass	464	10.7	9.5	601	10.1	8.8
Reread	91	6.6	8.2	282	7.5	7.2

Note. Saccade lengths are in character positions.

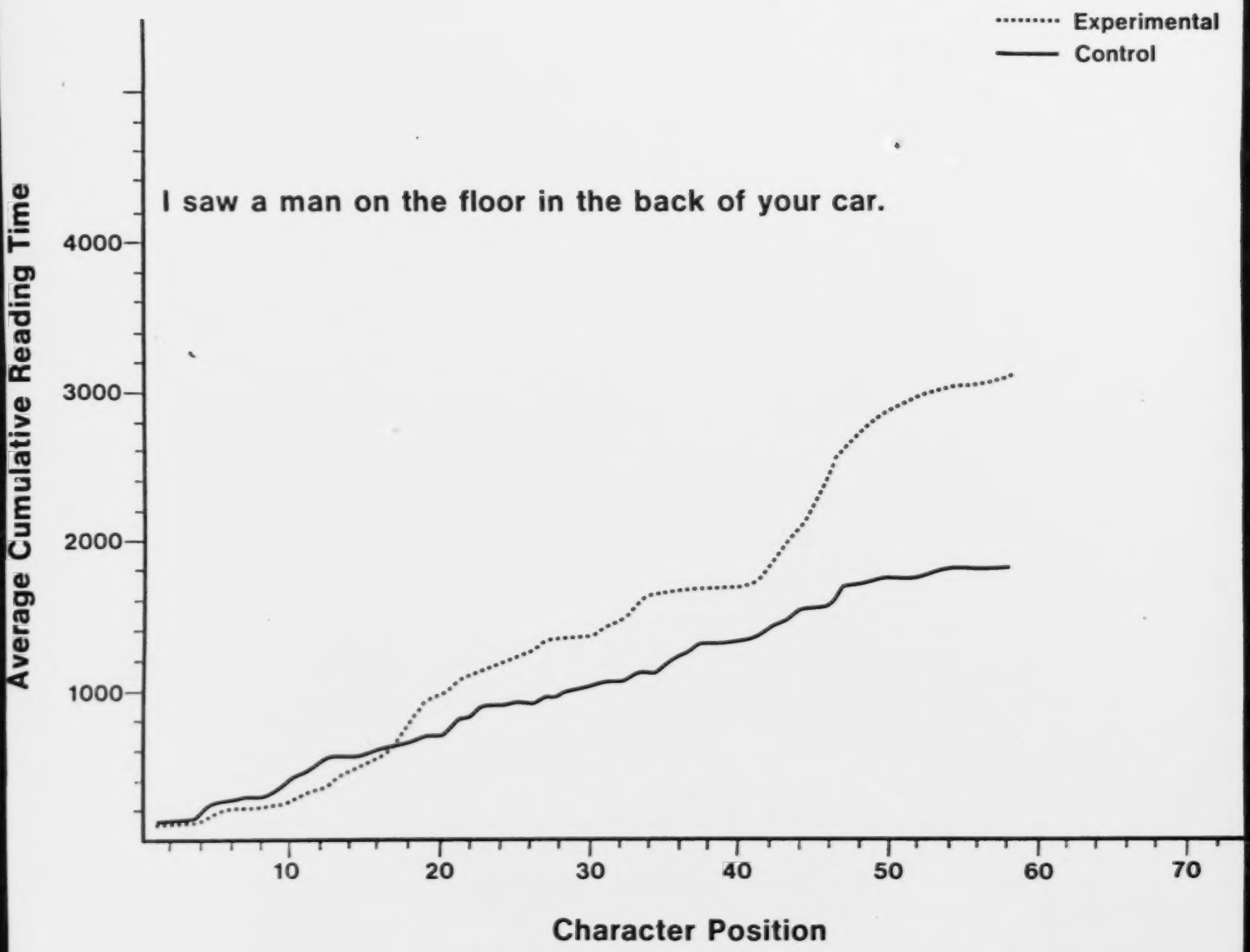
Figure Captions

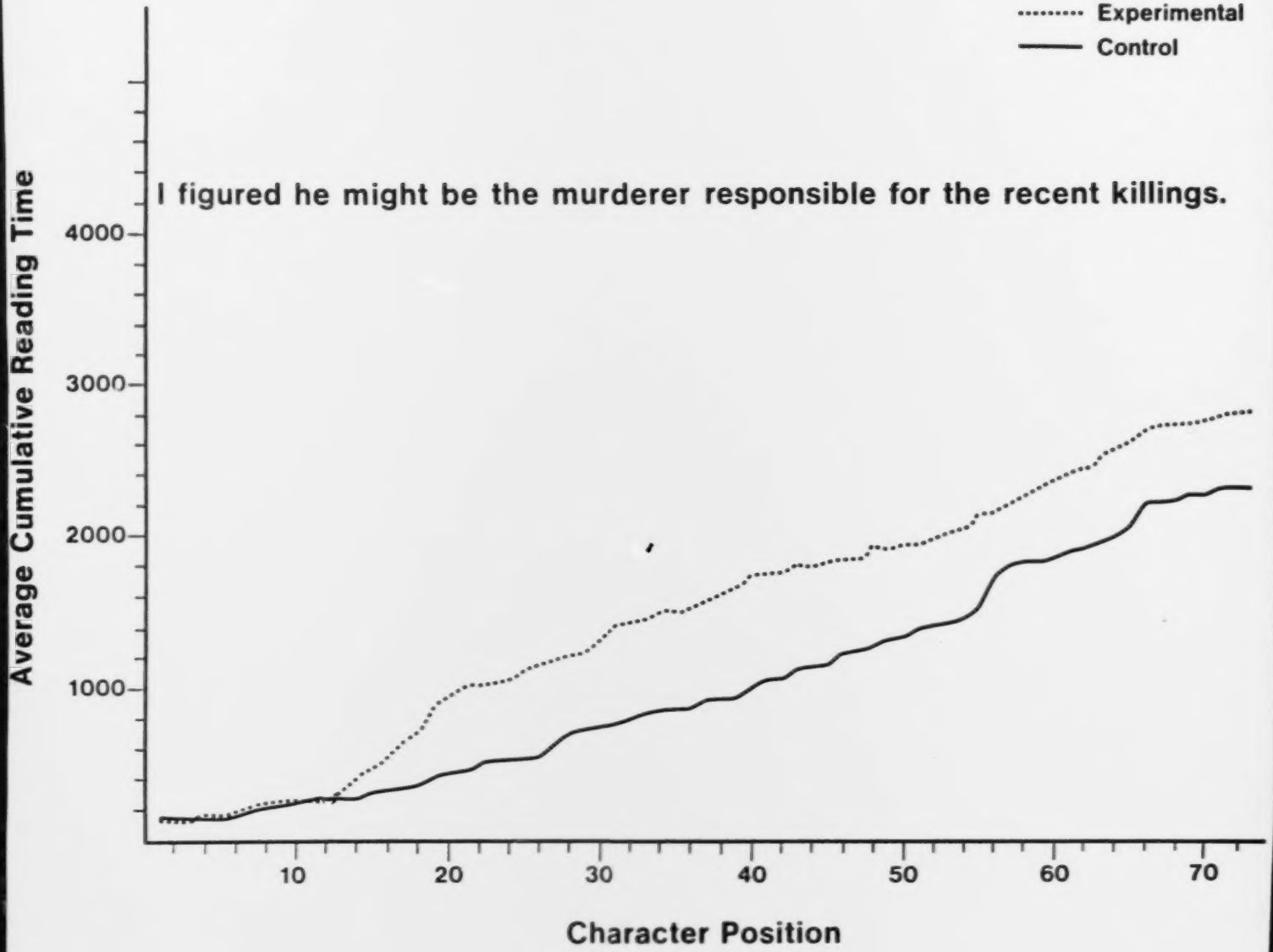
Figure 1. Mean cumulative reading times in milliseconds for each character position on the second selected line of the Gabriel passage in experimental and control versions.

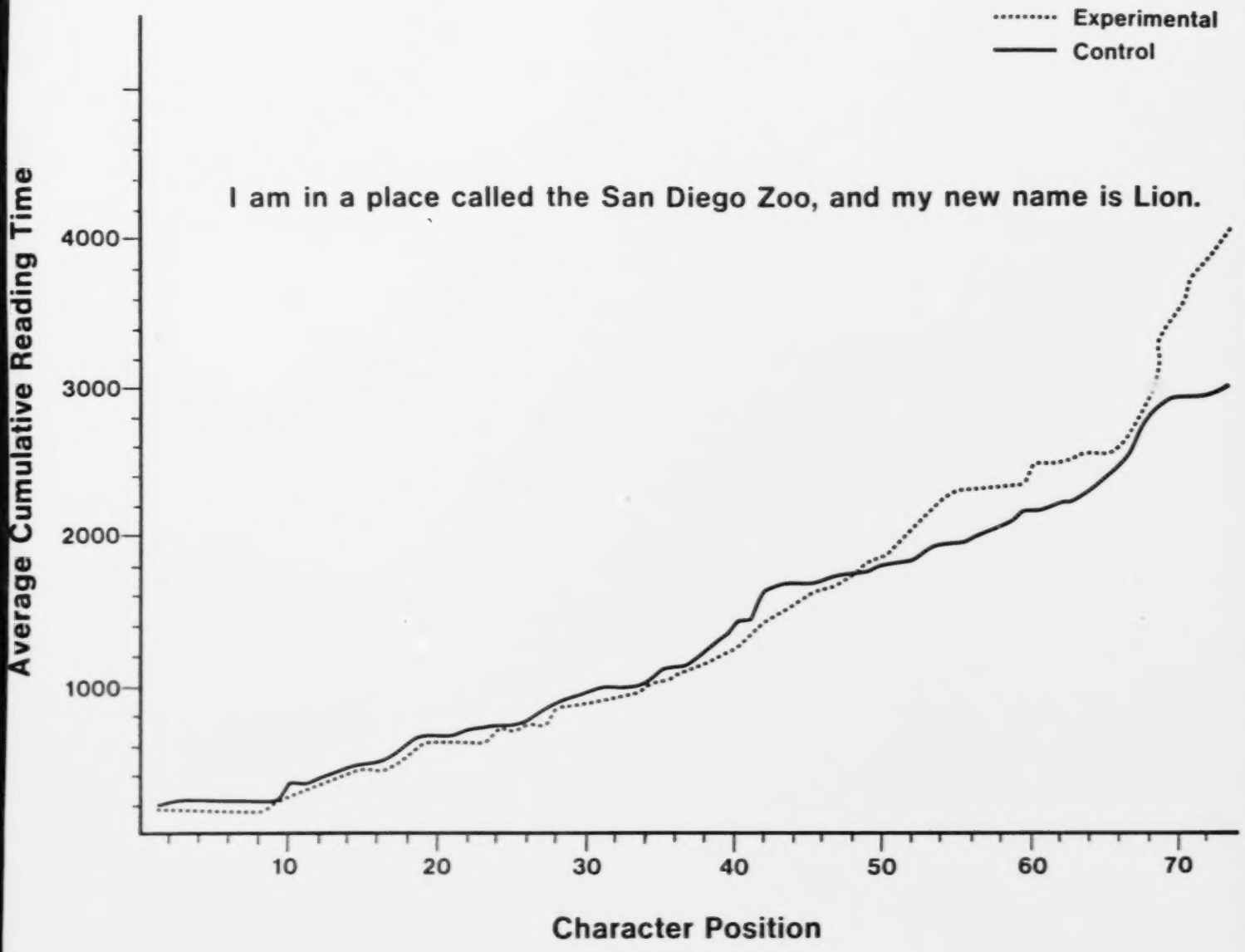
Figure 2. Mean cumulative reading times in milliseconds for each character position on the third selected line of the Gabriel passage in experimental and control versions.

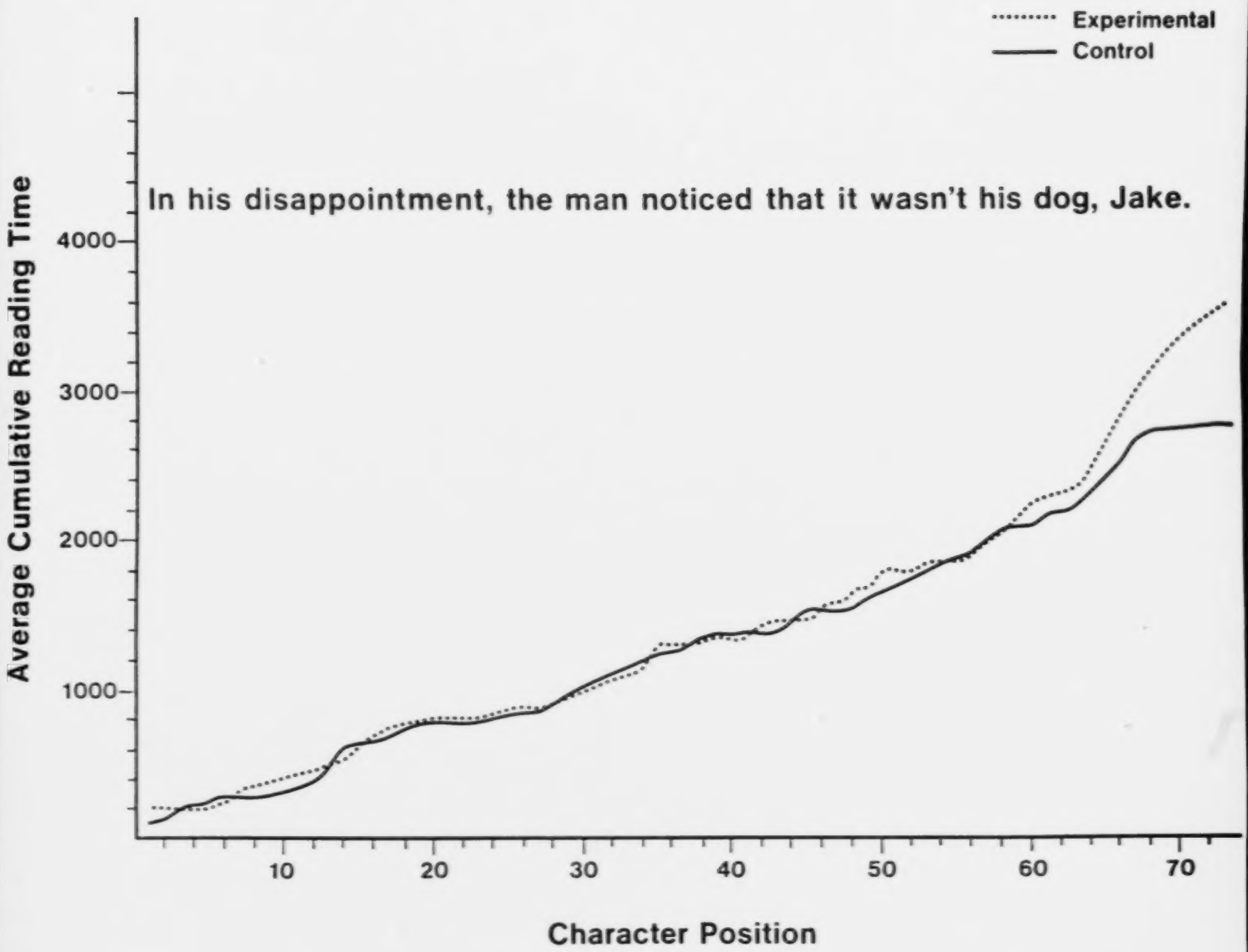
Figure 3. Mean cumulative reading times in milliseconds for each character position on the selected line of the Lion passage in experimental and control versions.

Figure 4. Mean cumulative reading times in milliseconds for each character position on the first selected line of the Sally passage in experimental and control versions.


Experimental
Control
I saw a man on the floor in the back of your car.
Average Cumulative Reading Time
4000
3000
2000
1000
10
20
30
40
50
60
70
Character Position


Experimental
Control
I figured he might be the murderer responsible for the recent killings.
Average Cumulative Reading Time
4000
3000
2000
1000
10
20
30
40
50
60
70
Character Position


Experimental
Control
I am in a place called the San Diego Zoo, and my new name is Lion.
Average Cumulative Reading Time
4000
3000
2000
1000
10
20
30
40
50
60
70
Character Position


Experimental
Control
In his disappointment, the man noticed that it wasn't his dog, Jake.
Average Cumulative Reading Time
4000
3000
2000
1000
10
20
30
40
50
60
70
Character Position